FIG. 1

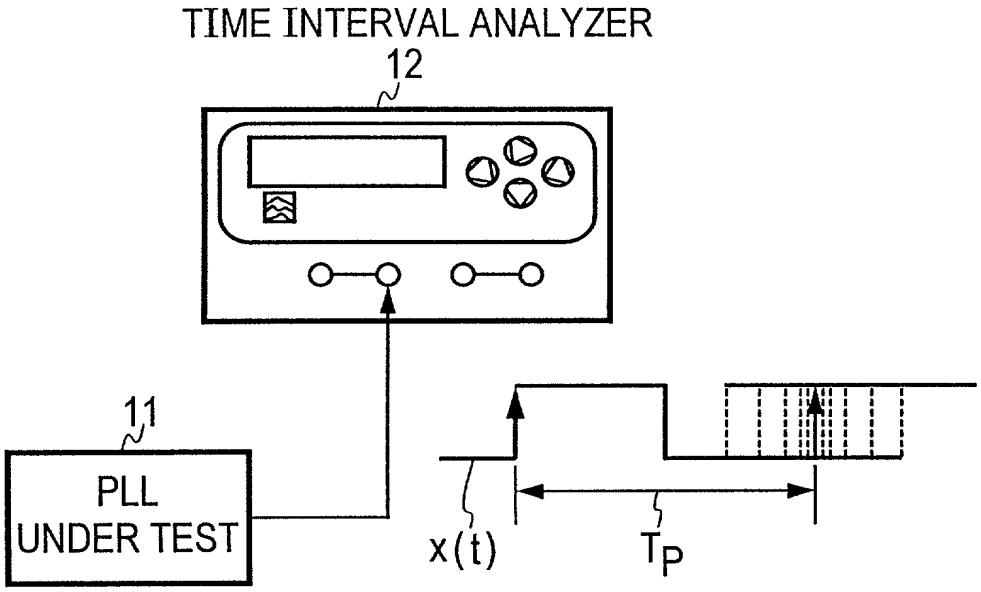

TIME INTERVAL ANALYZER
12
11
PLL
UNDER TEST
x(t)
T_P

FIG. 2

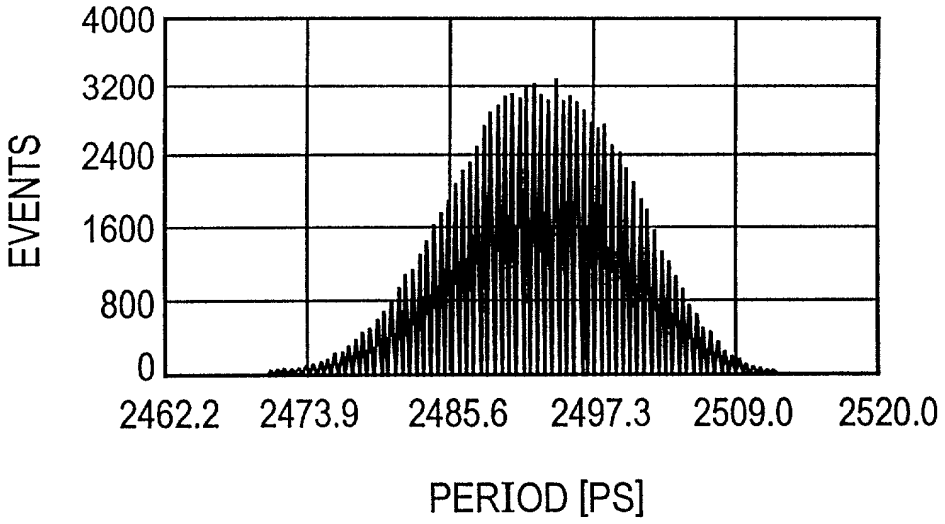

4000
3200
2400
1600
800
0
EVENTS
2462.2
2473.9
2485.6
2497.3
2509.0
2520.0
PERIOD [PS]

FIG. 3

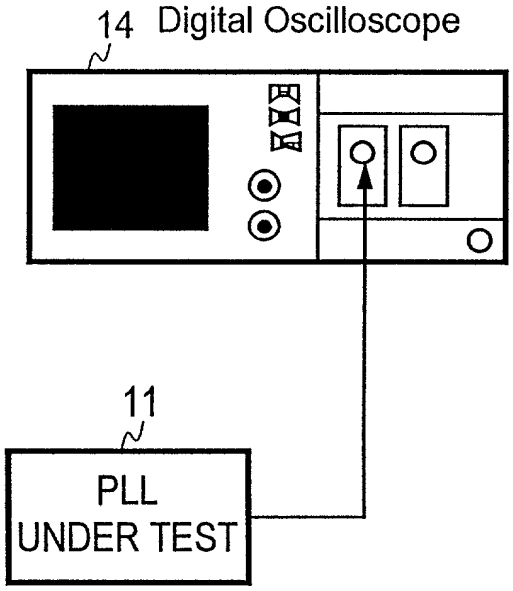

14 Digital Oscilloscope
11
PLL
UNDER TEST

FIG. 4

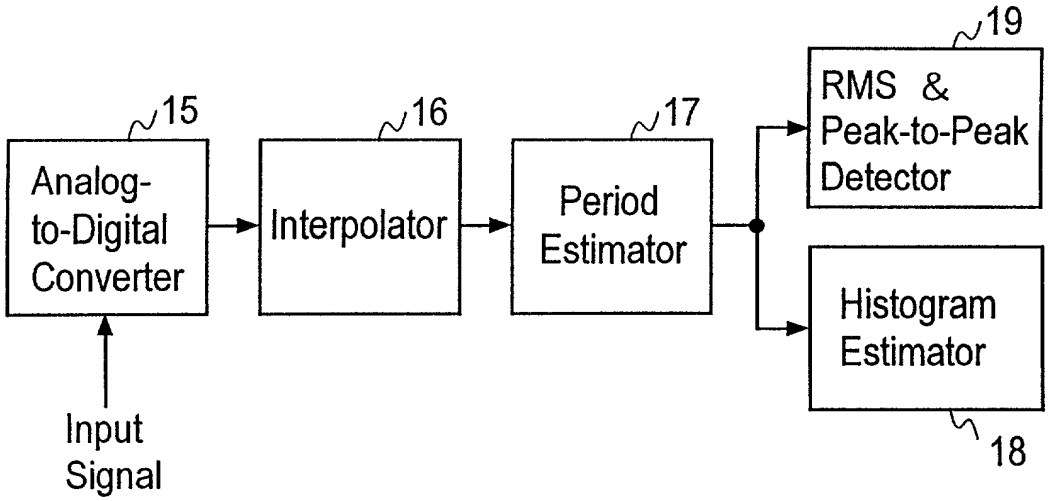

15
Analog-
to-Digital
Converter
16
Interpolator
17
Period
Estimator
19
RMS &
Peak-to-Peak
Detector
Histogram
Estimator
18
Input
Signal

FIG. 5A

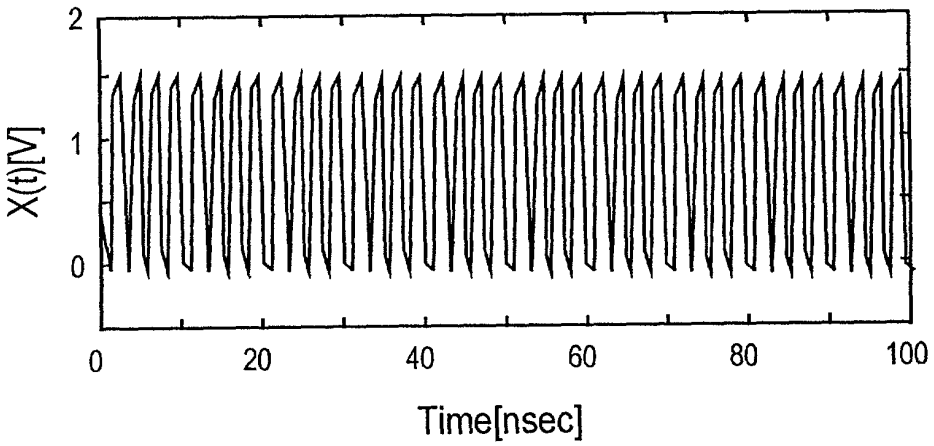
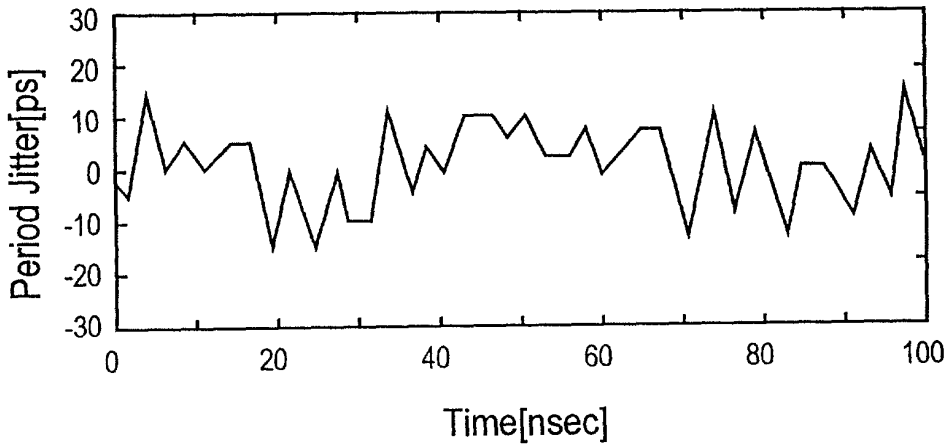

2
1
0
X(t)[V]
0
20
40
60
80
100
Time[nsec]

FIG. 5B


30
20
10
0
-10
-20
-30
Period Jitter[ps]
0
20
40
60
80
100
Time[nsec]

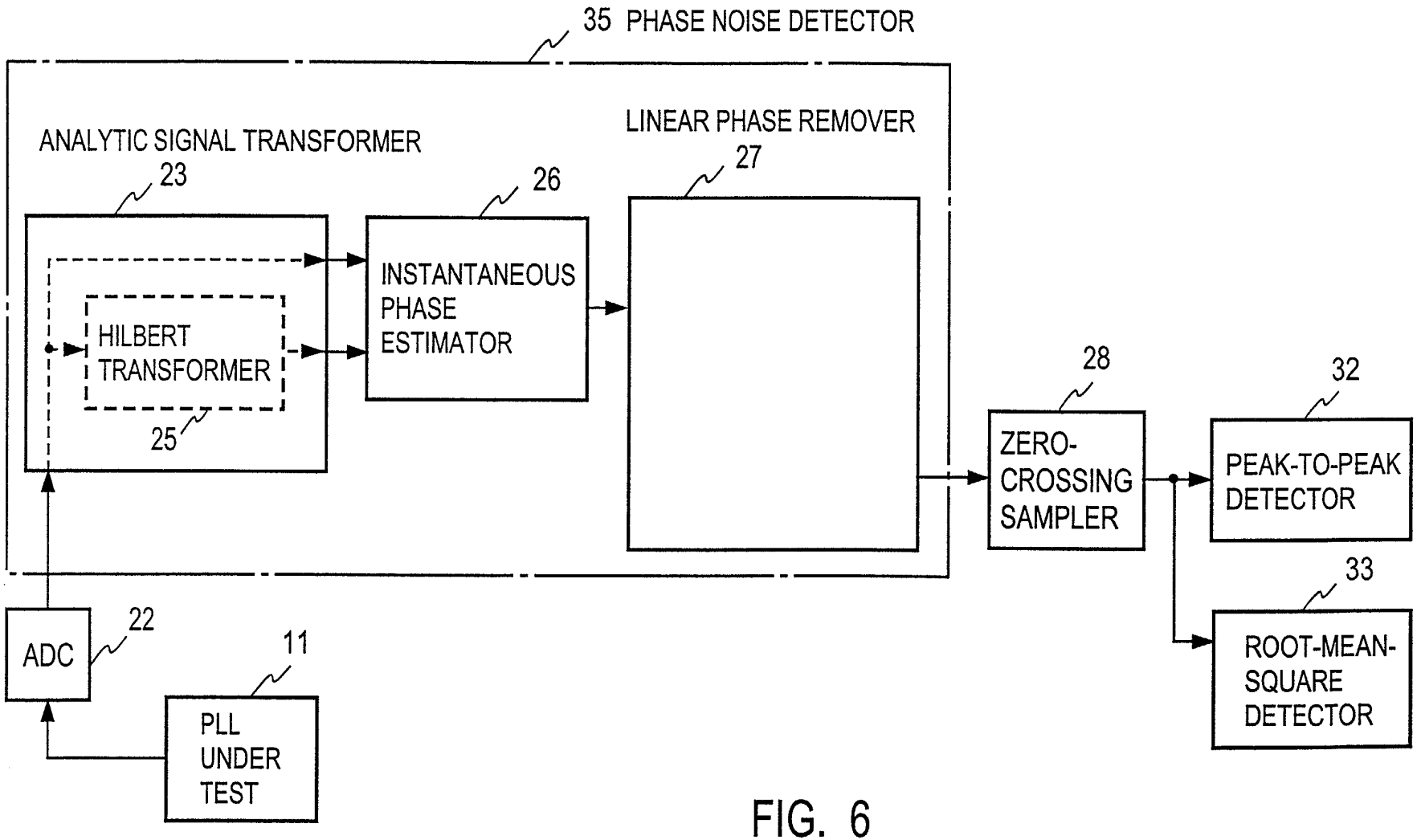
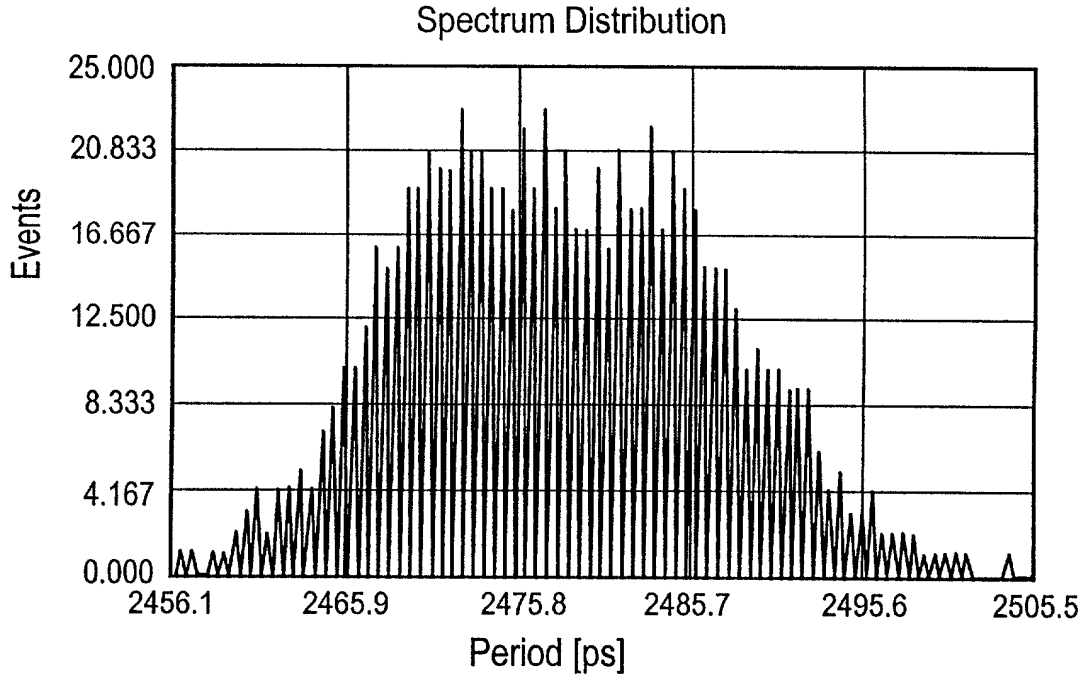


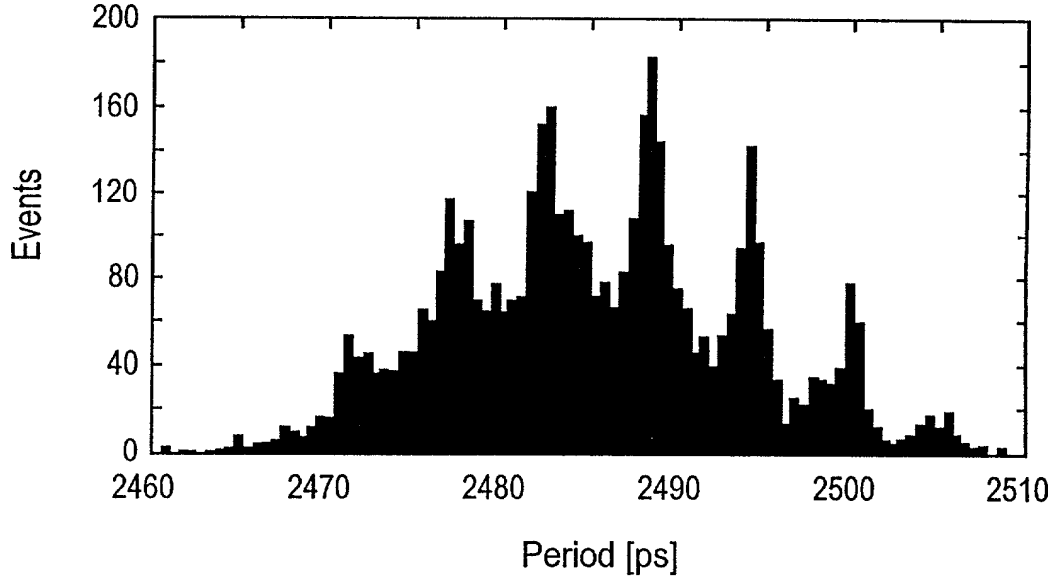
FIG. 6

FIG. 7A



Number of Events : 10,000
RMS Jitter : 7.72 ps
Peak-to-Peak Jitter : 48.2 ps

FIG. 7B



Number of Events : 4,573
RMS Jitter : 8.47 ps
Peak-to-Peak Jitter : 52.0 ps

FIG. 8

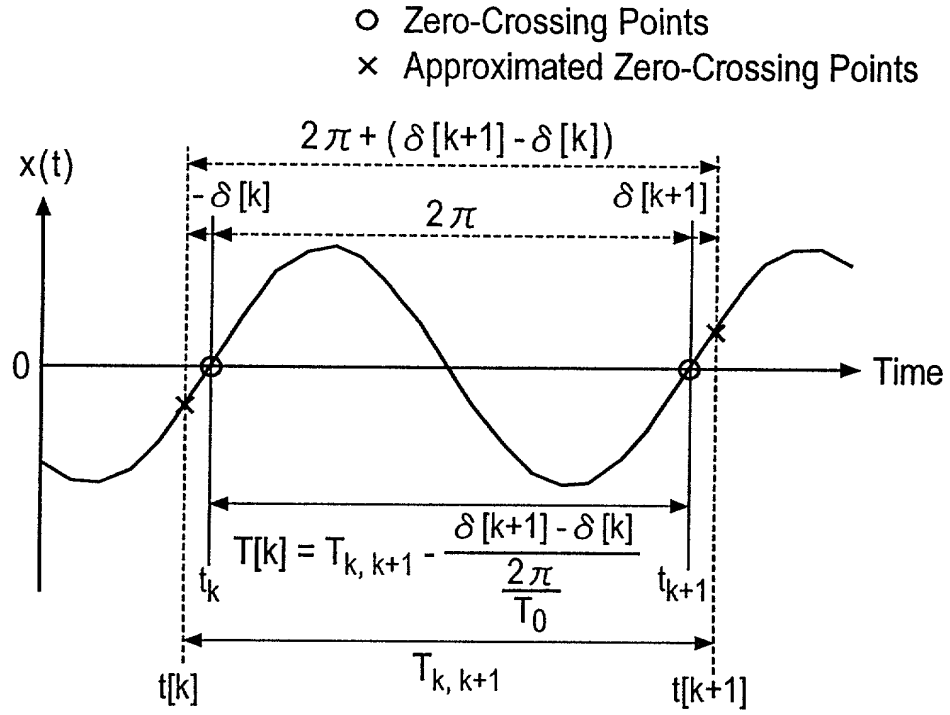


FIG. 9

Method	No. of Events	J_{RMS}	J_{PP}
Proposed Method Without Jitter Sequence Correction	21,431	2.4535 ps (+0.53%)	8.0029 ps (+15.9%)
Proposed Method with Jitter Sequence Correction	21,431	2.4404 ps (-0.004%)	6.9054 ps (+0.04%)
Ideal Value	--	2.4405 ps	6.9028 ps

FIG. 10A

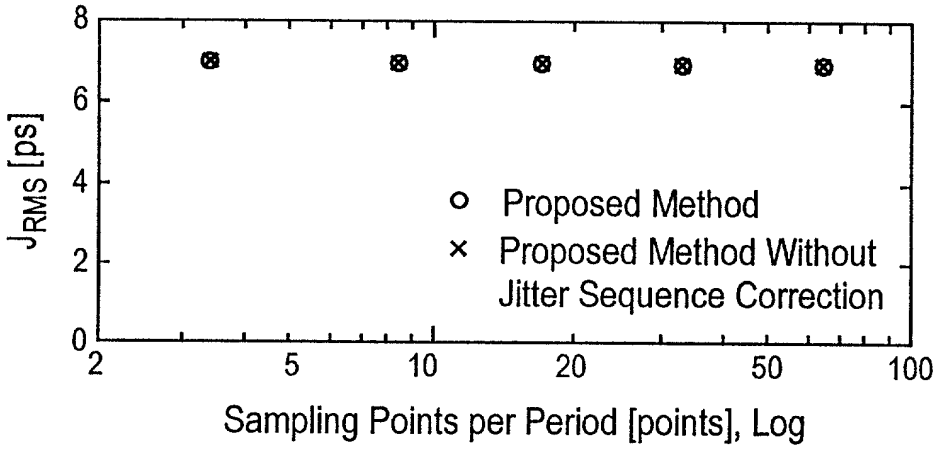


FIG. 10B

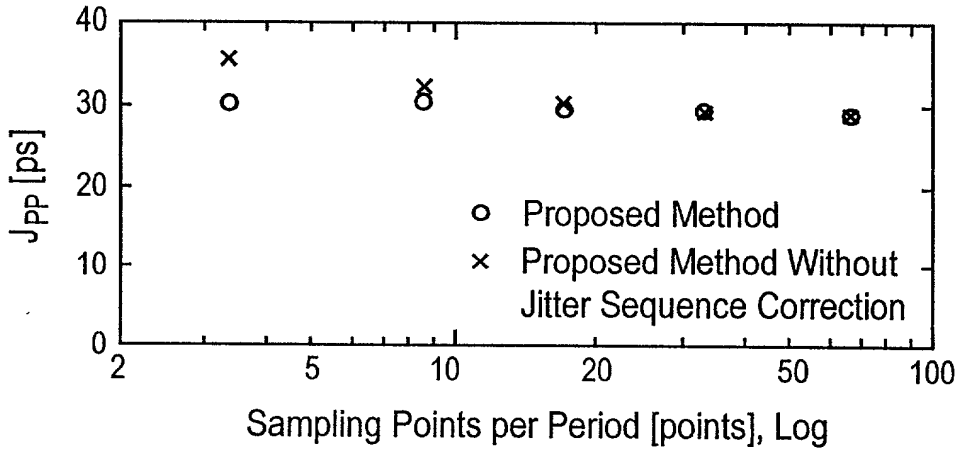


FIG. 11

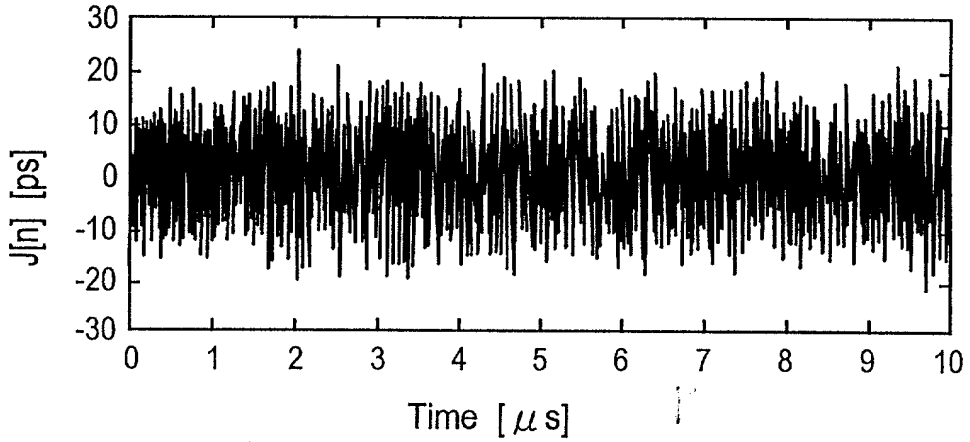


FIG. 12A

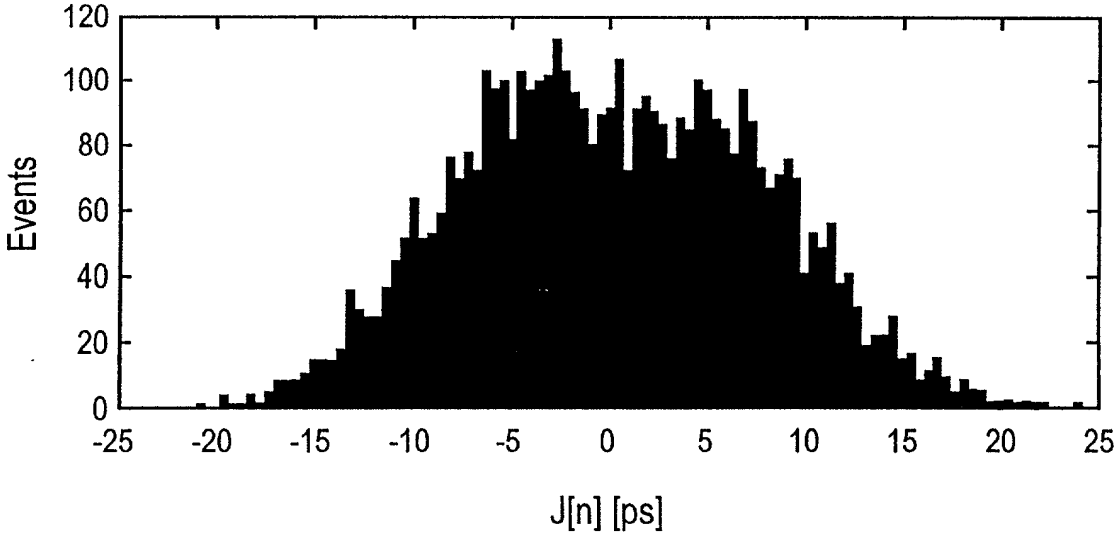


FIG. 12B

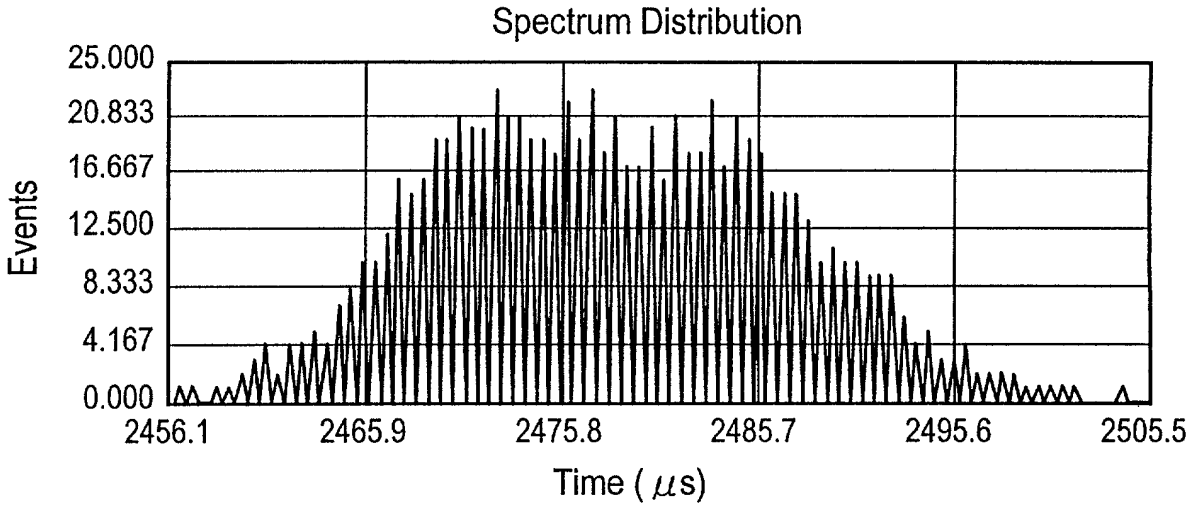


FIG. 13

Method	No. of Events	J_{RMS}	J_{PP}
Time Interval Analyzer	10,000	7.72 ps	48.2 ps
Proposed Method	4,696	7.49 ps	45.7 ps
Difference	-53 %	-3.0 %	+1.5 %

FIG. 14

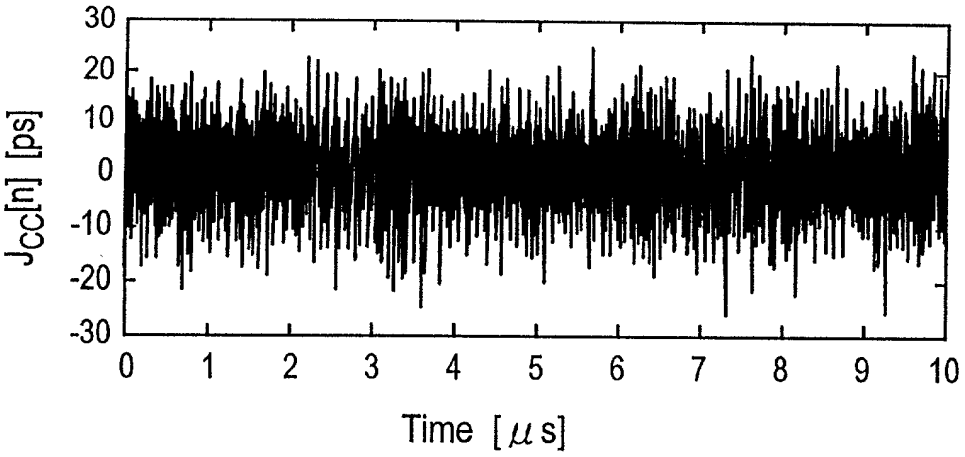


FIG. 15

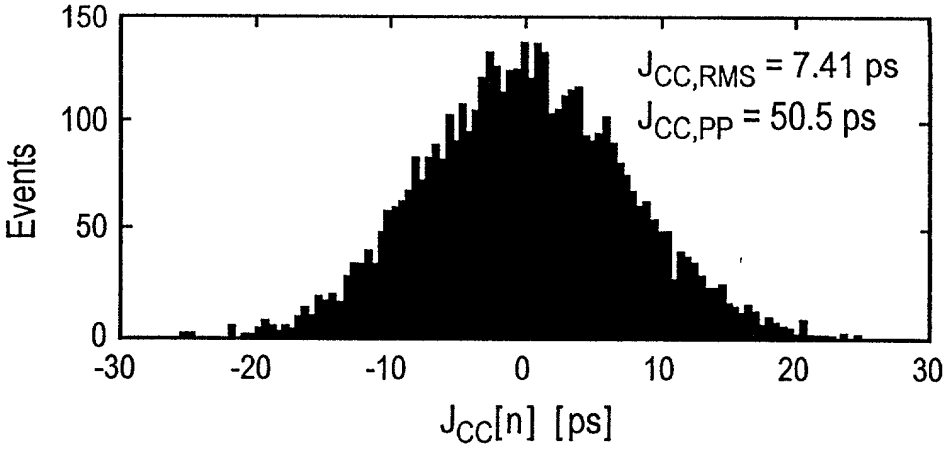


FIG. 16

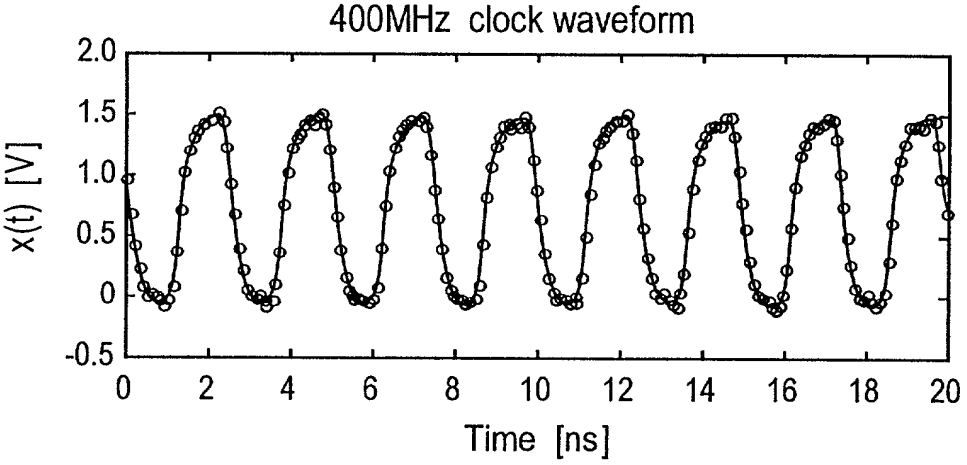


FIG. 17

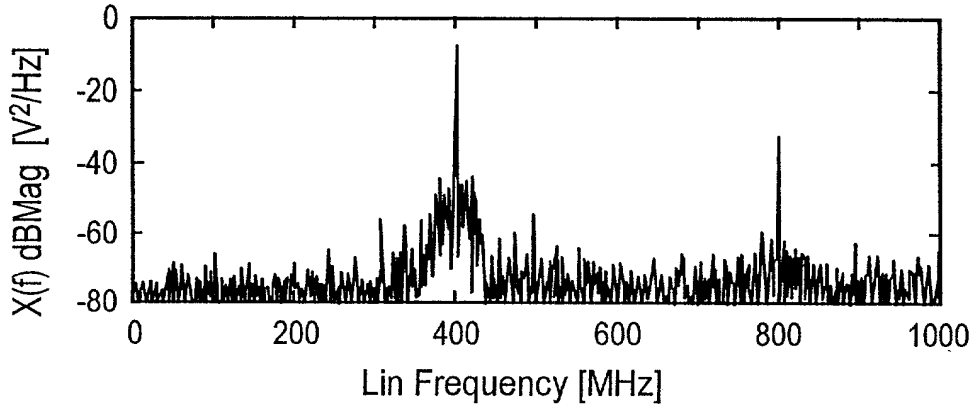


FIG. 18

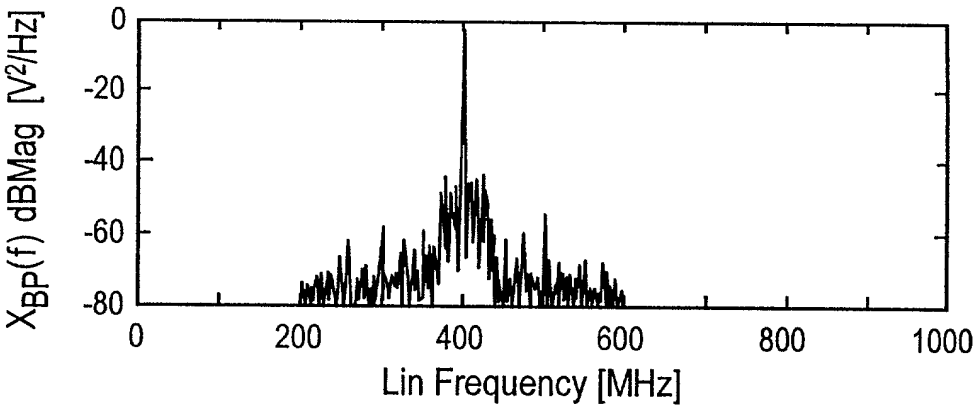


FIG. 19

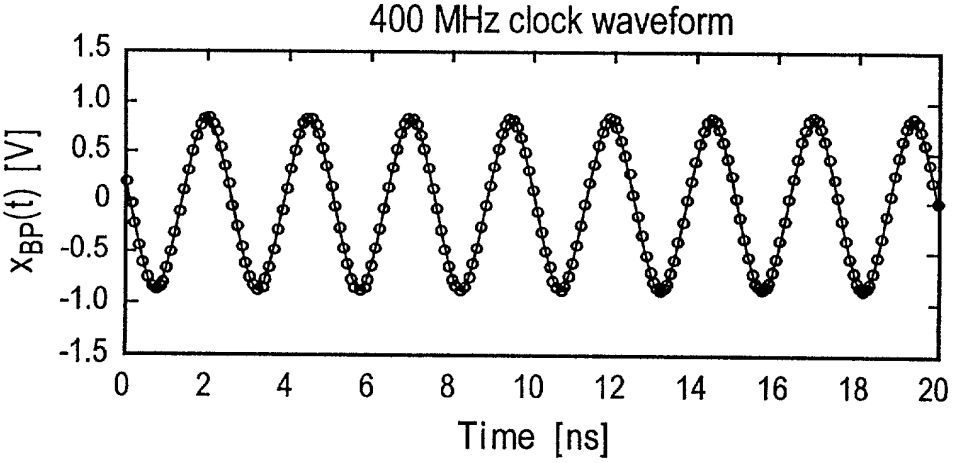


FIG. 20

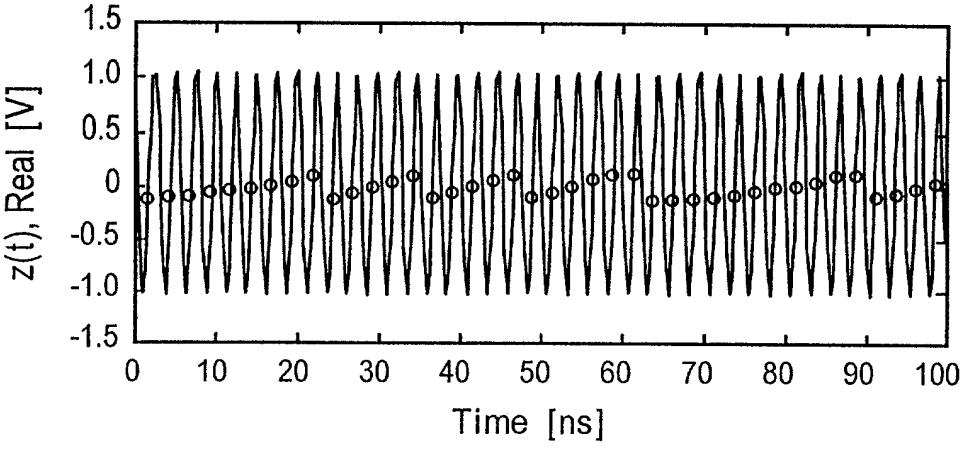


FIG. 21

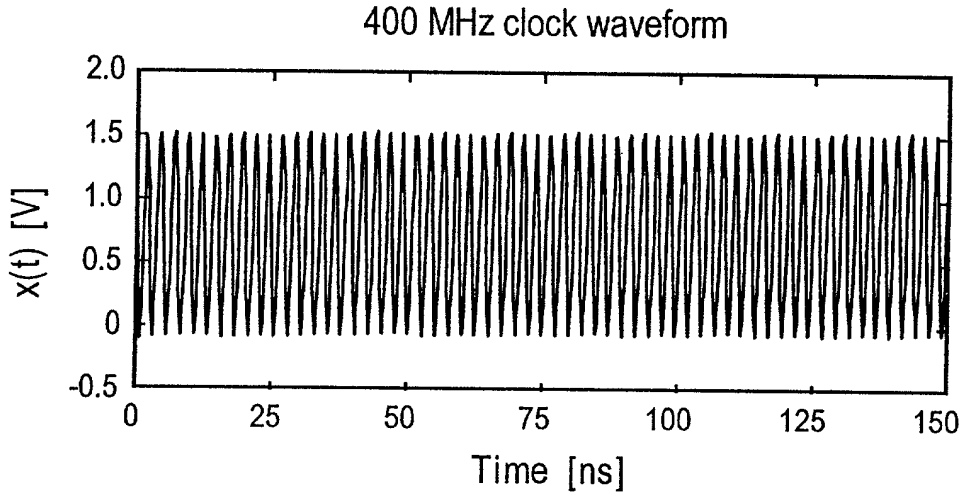

400 MHz clock waveform
2.0
1.5
1.0
0.5
0
-0.5
x(t) [V]
0
25
50
75
100
125
150
Time [ns]

FIG. 22

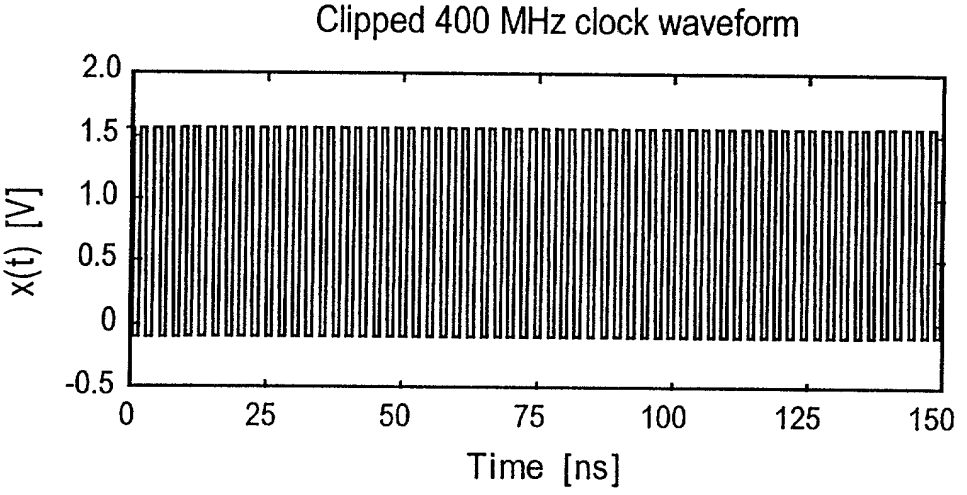

Clipped 400 MHz clock waveform
2.0
1.5
1.0
0.5
0
-0.5
x(t) [V]
0
25
50
75
100
125
150
Time [ns]

FIG.23

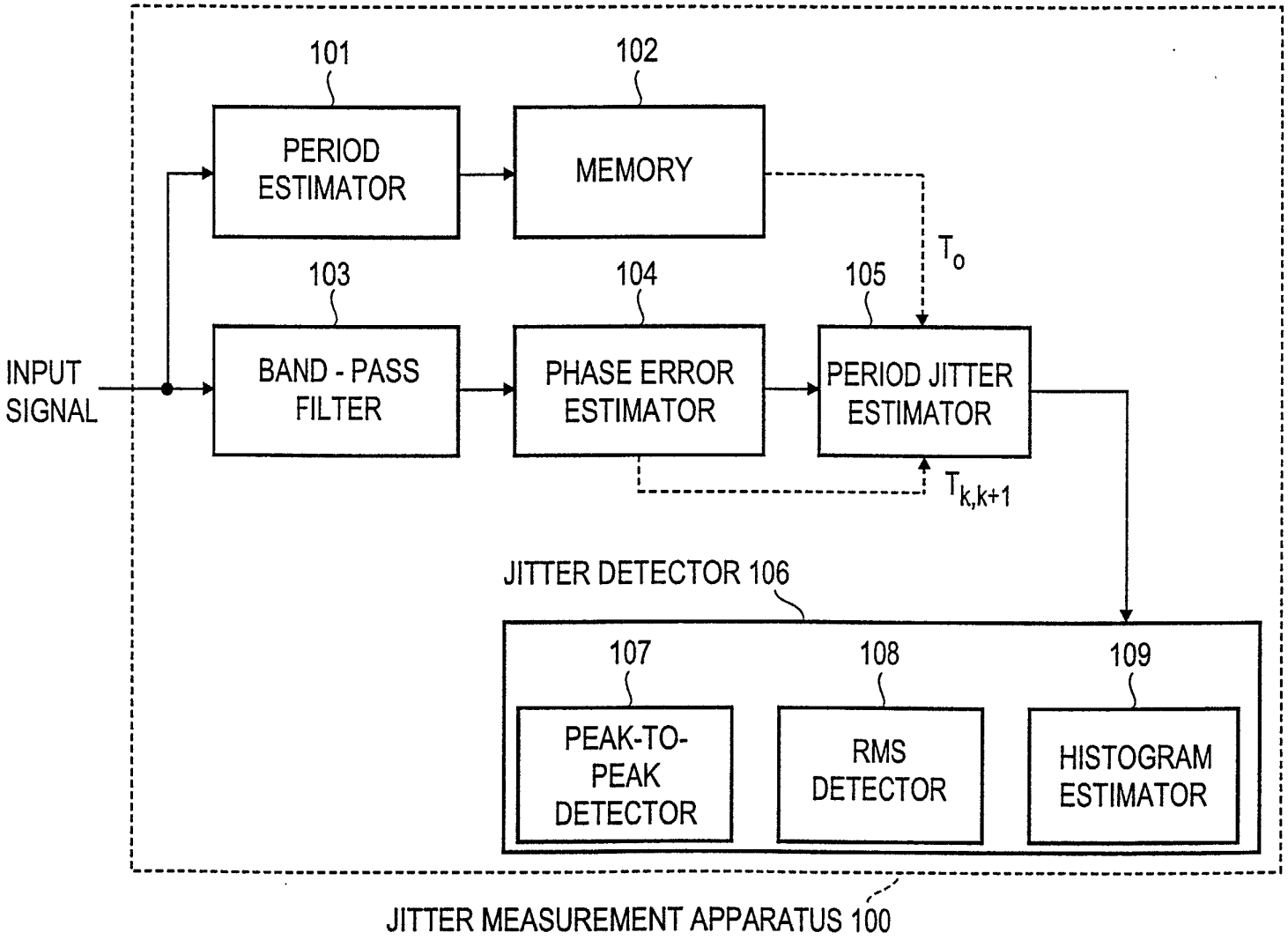

101
102
PERIOD ESTIMATOR
MEMORY
T_o
103
104
105
INPUT SIGNAL
BAND - PASS FILTER
PHASE ERROR ESTIMATOR
PERIOD JITTER ESTIMATOR
$T_{k,k+1}$
JITTER DETECTOR 106
107
108
109
PEAK-TO-PEAK DETECTOR
RMS DETECTOR
HISTOGRAM ESTIMATOR
JITTER MEASUREMENT APPARATUS 100

FIG. 24

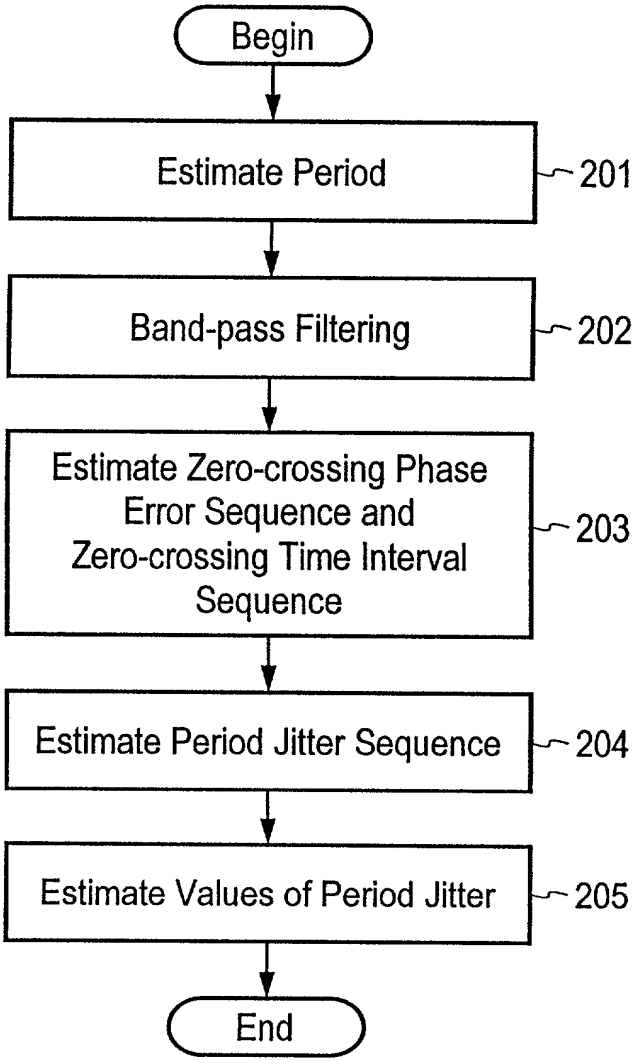

Begin
Estimate Period
201
Band-pass Filtering
202
Estimate Zero-crossing Phase Error Sequence and Zero-crossing Time Interval Sequence
203
Estimate Period Jitter Sequence
204
Estimate Values of Period Jitter
205
End

FIG.25

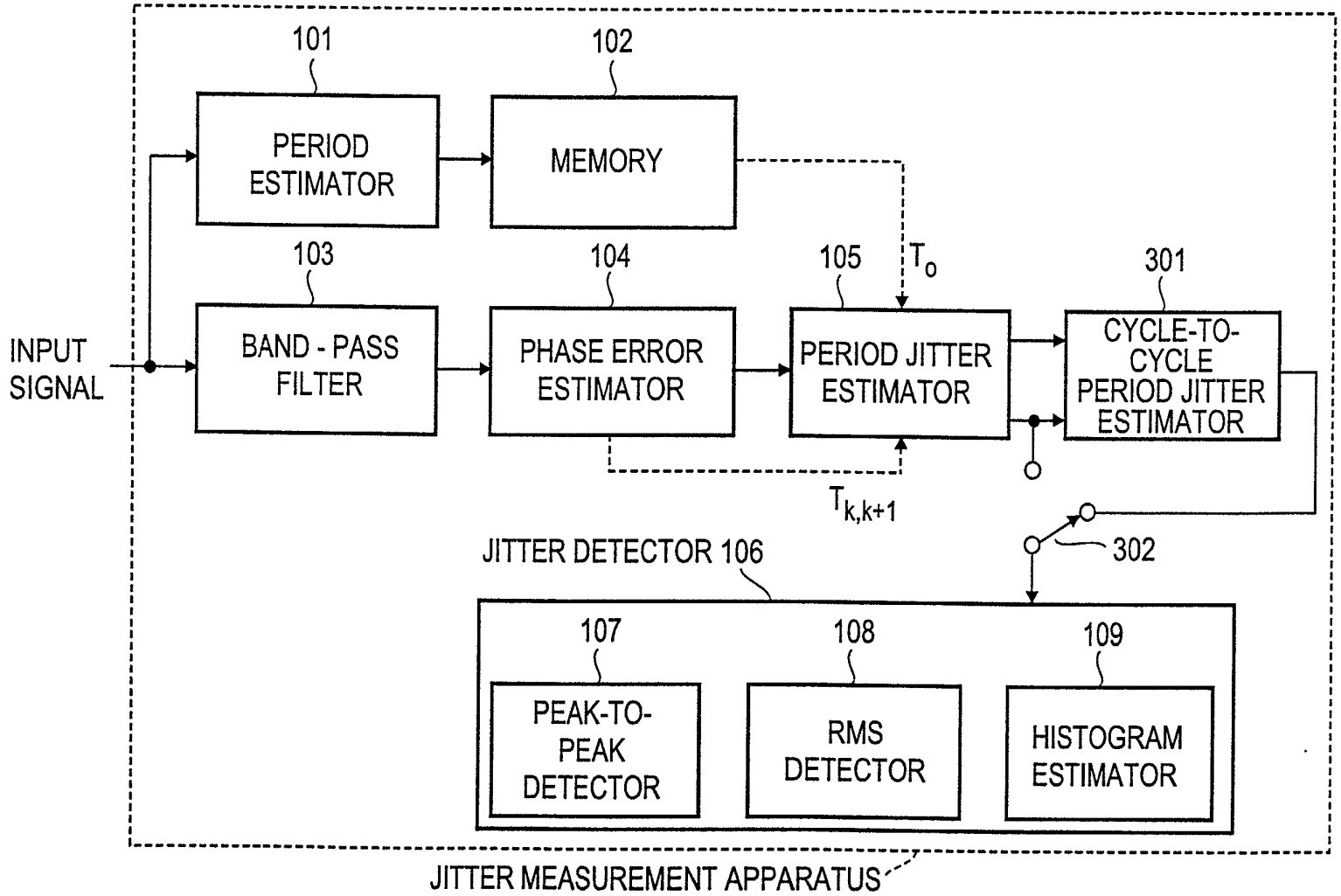


FIG. 26

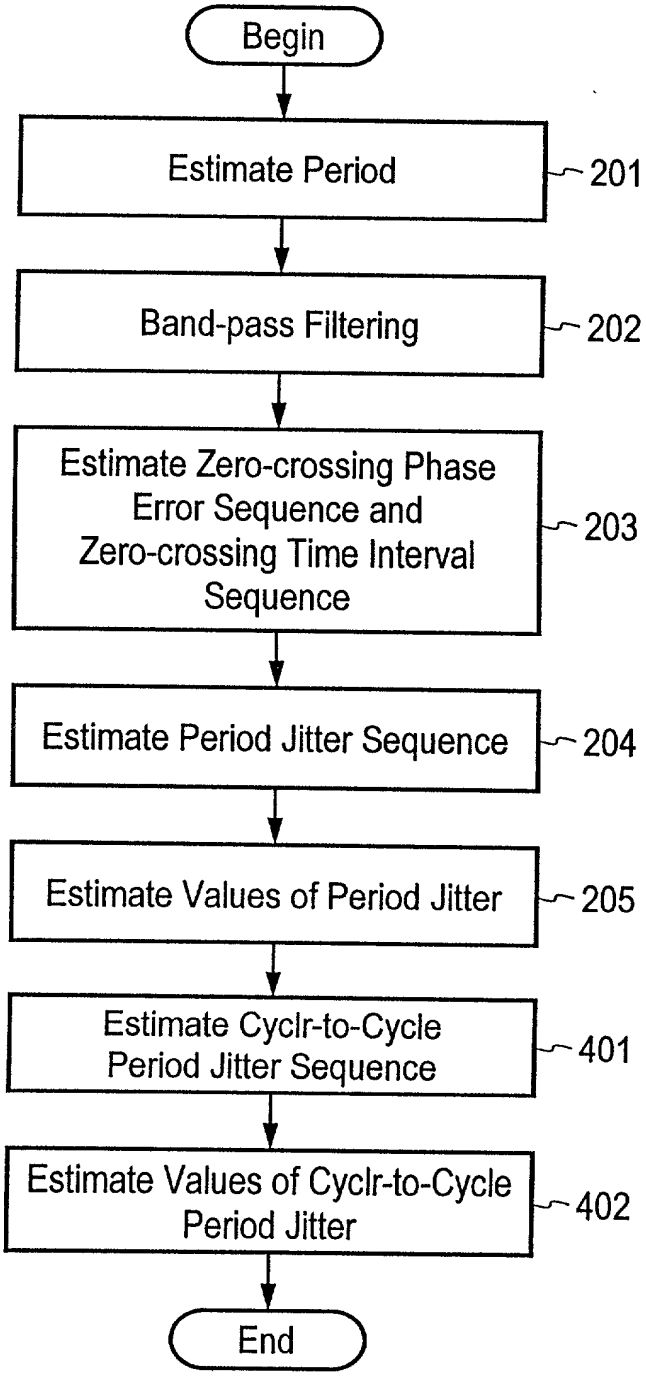

Begin
Estimate Period
201
Band-pass Filtering
202
Estimate Zero-crossing Phase Error Sequence and Zero-crossing Time Interval Sequence
203
Estimate Period Jitter Sequence
204
Estimate Values of Period Jitter
205
Estimate Cyclr-to-Cycle Period Jitter Sequence
401
Estimate Values of Cyclr-to-Cycle Period Jitter
402
End

FIG.27

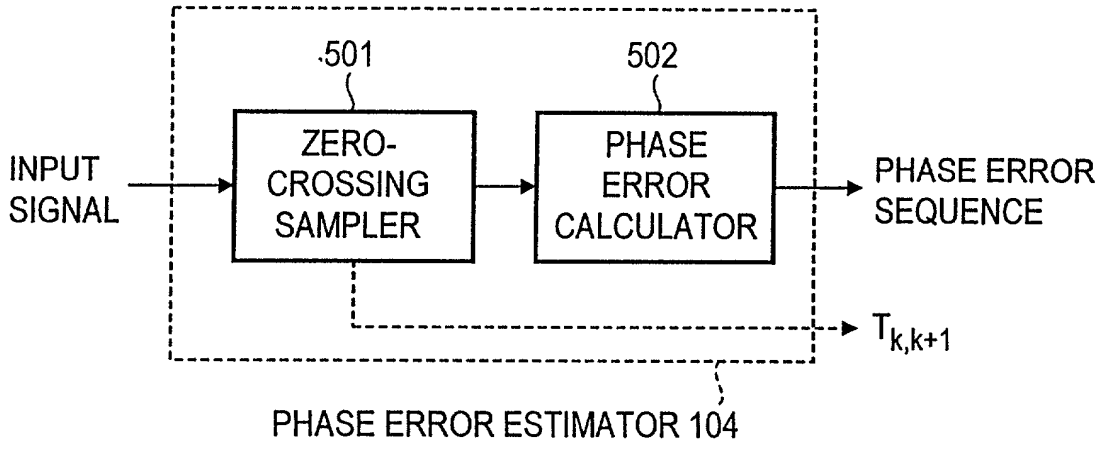

501
502
INPUT SIGNAL
ZERO-CROSSING SAMPLER
PHASE ERROR CALCULATOR
PHASE ERROR SEQUENCE
$T_{k,k+1}$
PHASE ERROR ESTIMATOR 104

FIG.29

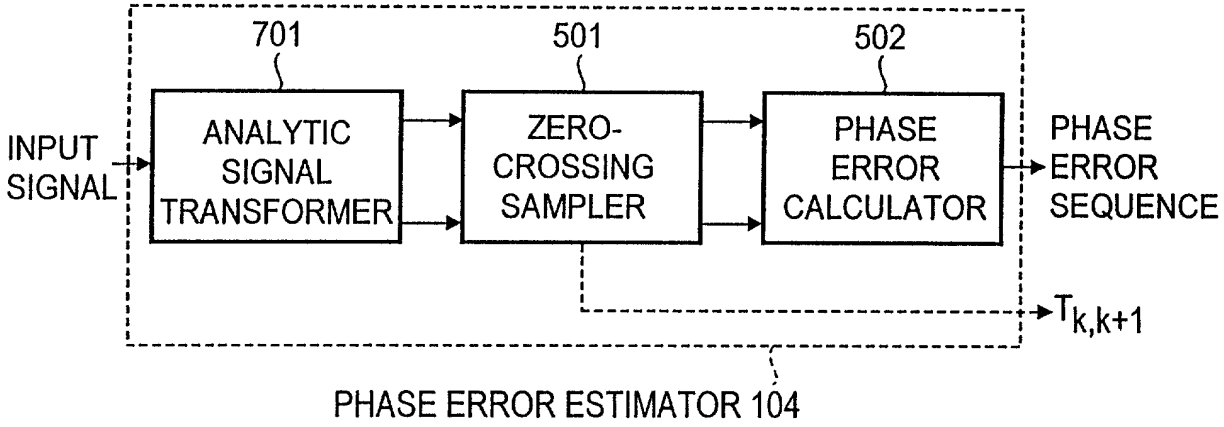

701
501
502
INPUT SIGNAL
ANALYTIC SIGNAL TRANSFORMER
ZERO-CROSSING SAMPLER
PHASE ERROR CALCULATOR
PHASE ERROR SEQUENCE
$T_{k,k+1}$
PHASE ERROR ESTIMATOR 104

FIG. 28

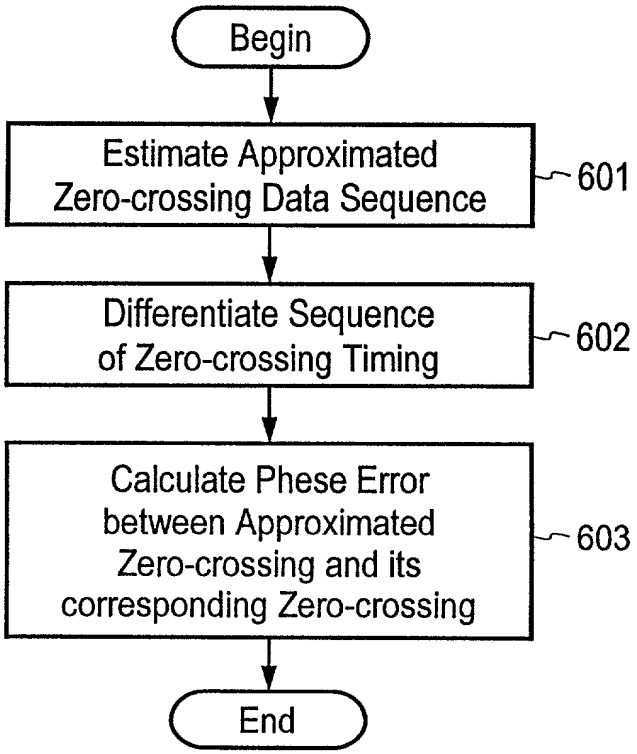

Begin
Estimate Approximated Zero-crossing Data Sequence
601
Differentiate Sequence of Zero-crossing Timing
602
Calculate Phese Error between Approximated Zero-crossing and its corresponding Zero-crossing
603
End

FIG. 30

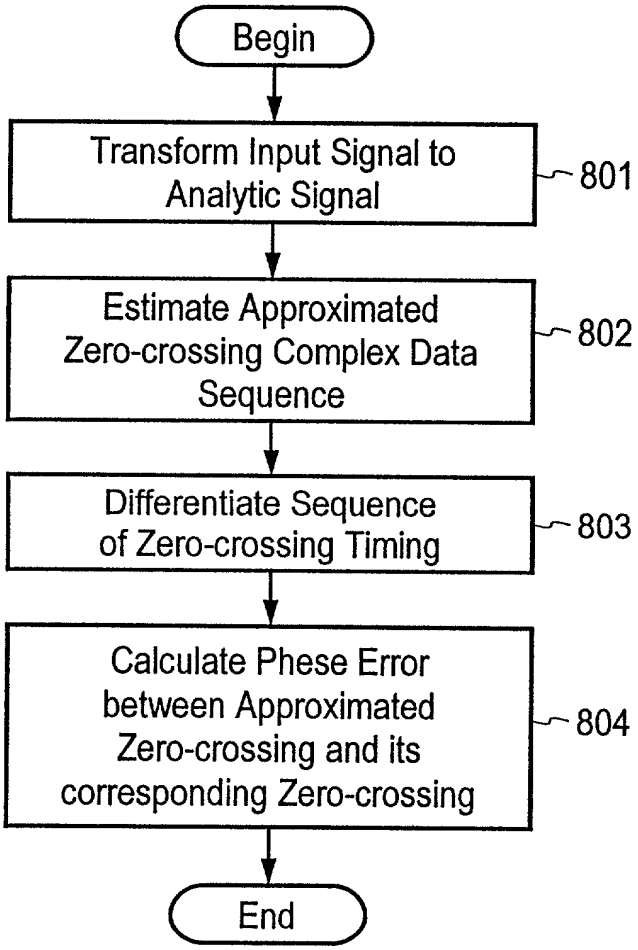

Begin
Transform Input Signal to Analytic Signal
801
Estimate Approximated Zero-crossing Complex Data Sequence
802
Differentiate Sequence of Zero-crossing Timing
803
Calculate Phese Error between Approximated Zero-crossing and its corresponding Zero-crossing
804
End

FIG.31

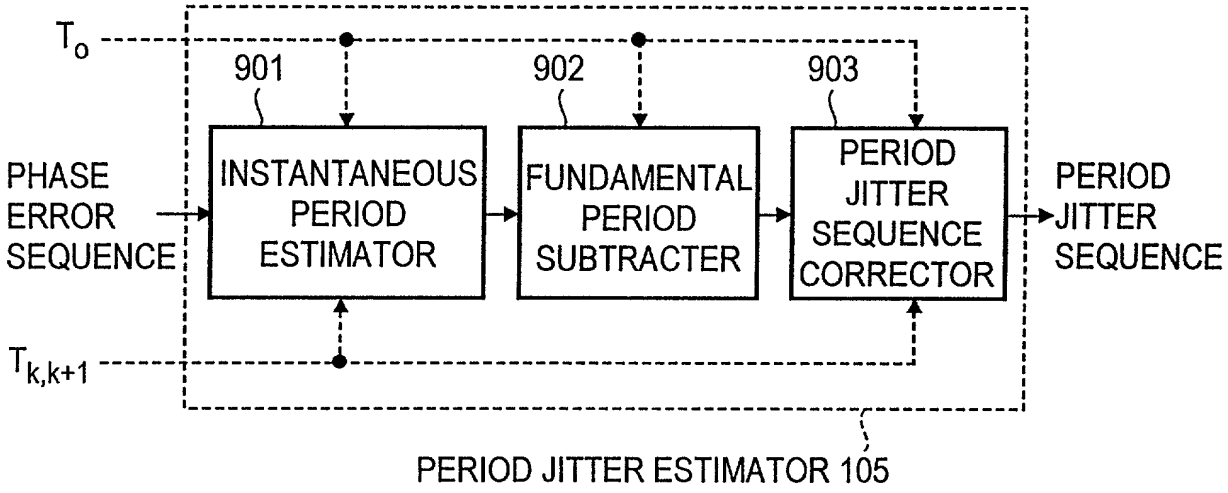

T_o
901
902
903
PHASE ERROR SEQUENCE
INSTANTANEOUS PERIOD ESTIMATOR
FUNDAMENTAL PERIOD SUBTRACTER
PERIOD JITTER SEQUENCE CORRECTOR
PERIOD JITTER SEQUENCE
$T_{k,k+1}$
PERIOD JITTER ESTIMATOR 105

FIG.33

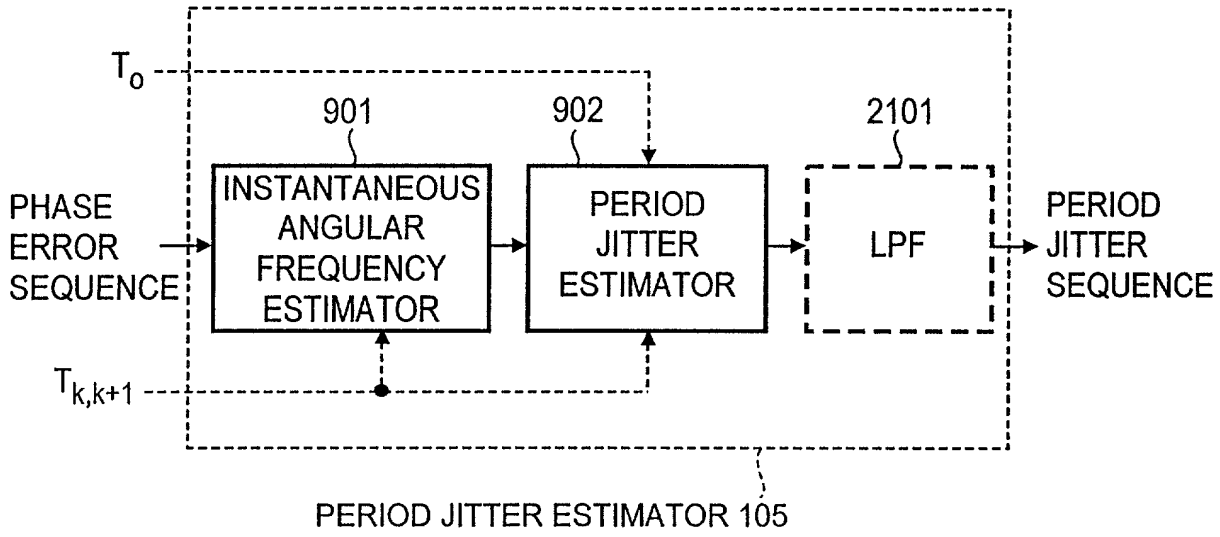

T_o
901
902
2101
PHASE ERROR SEQUENCE
INSTANTANEOUS ANGULAR FREQUENCY ESTIMATOR
PERIOD JITTER ESTIMATOR
LPF
PERIOD JITTER SEQUENCE
$T_{k,k+1}$
PERIOD JITTER ESTIMATOR 105

FIG. 32

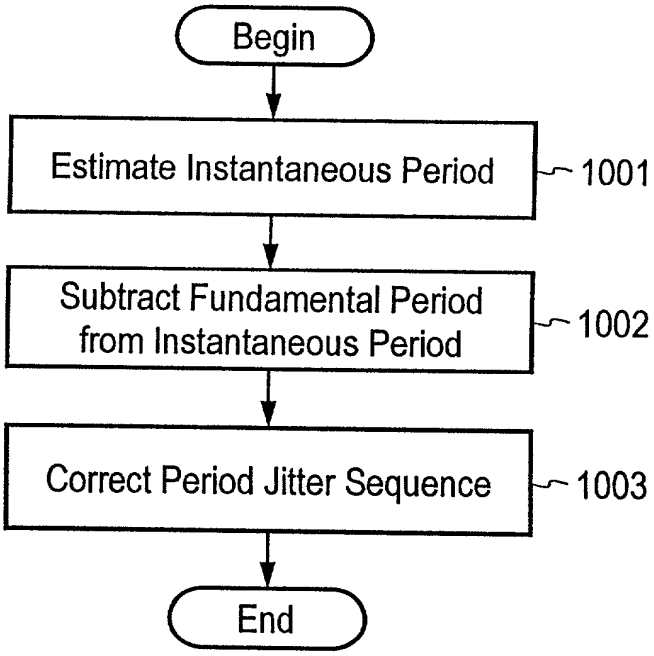

Begin
Estimate Instantaneous Period
1001
Subtract Fundamental Period from Instantaneous Period
1002
Correct Period Jitter Sequence
1003
End

FIG. 34

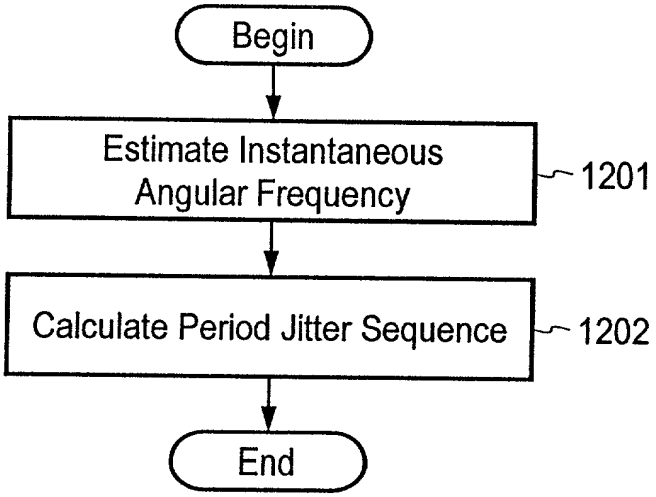

Begin
Estimate Instantaneous Angular Frequency
1201
Calculate Period Jitter Sequence
1202
End

FIG. 42

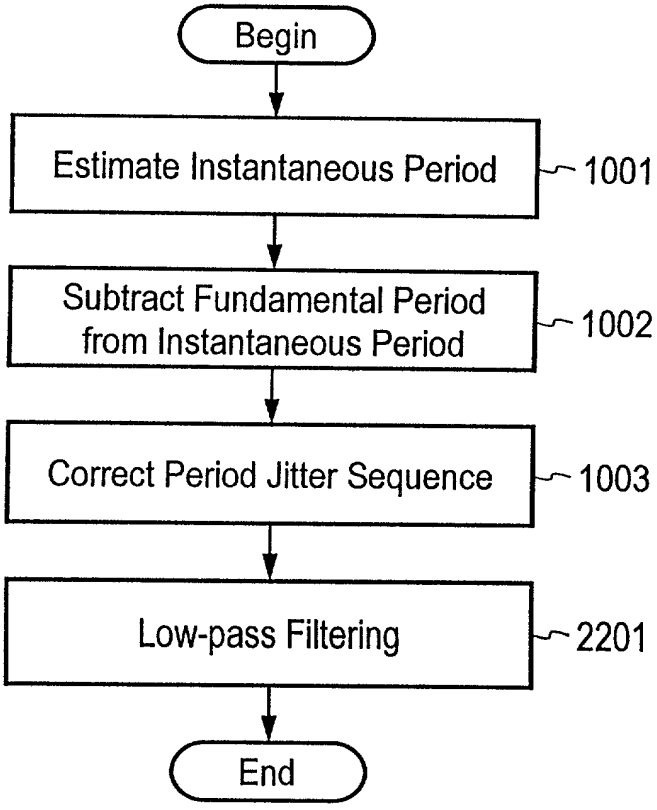

Begin
Estimate Instantaneous Period
1001
Subtract Fundamental Period from Instantaneous Period
1002
Correct Period Jitter Sequence
1003
Low-pass Filtering
2201
End

FIG.35

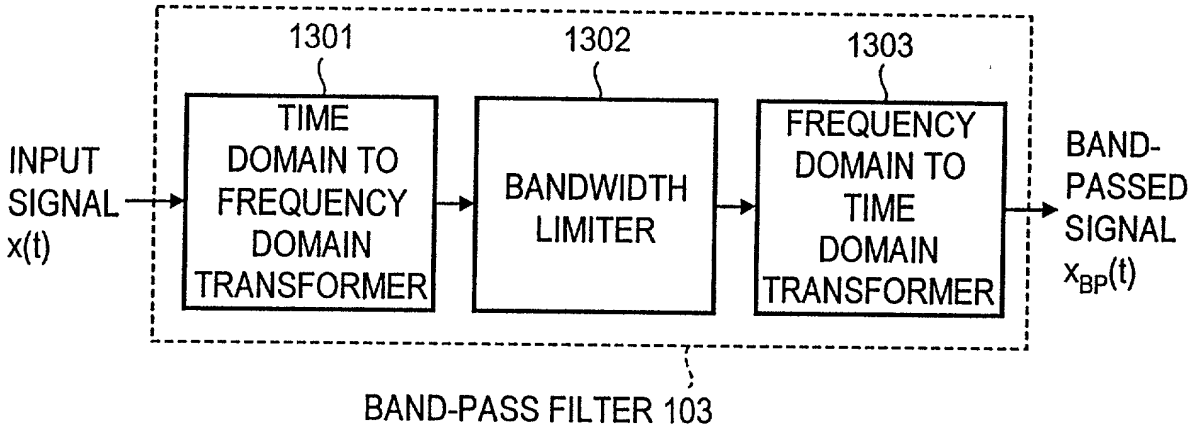

1301
1302
1303
INPUT SIGNAL x(t)
TIME DOMAIN TO FREQUENCY DOMAIN TRANSFORMER
BANDWIDTH LIMITER
FREQUENCY DOMAIN TO TIME DOMAIN TRANSFORMER
BAND-PASSED SIGNAL $x_{BP}(t)$
BAND-PASS FILTER 103

FIG. 36

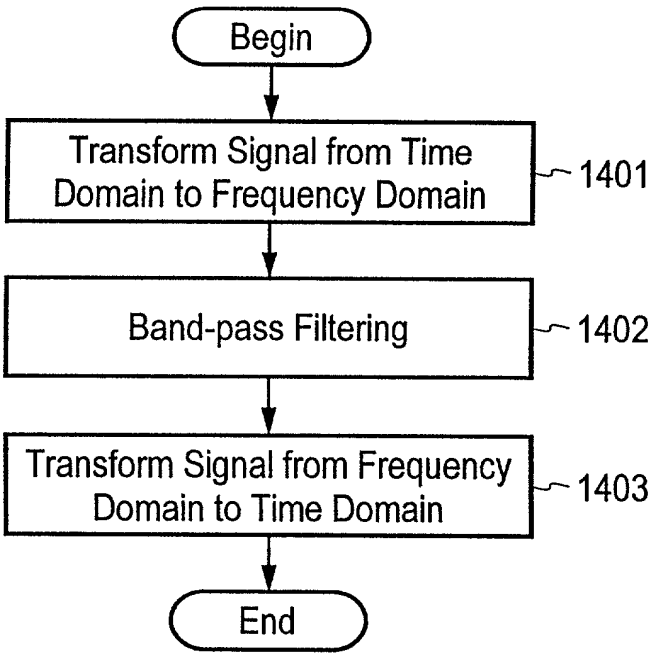

Begin
Transform Signal from Time Domain to Frequency Domain
1401
Band-pass Filtering
1402
Transform Signal from Frequency Domain to Time Domain
1403
End

FIG.37

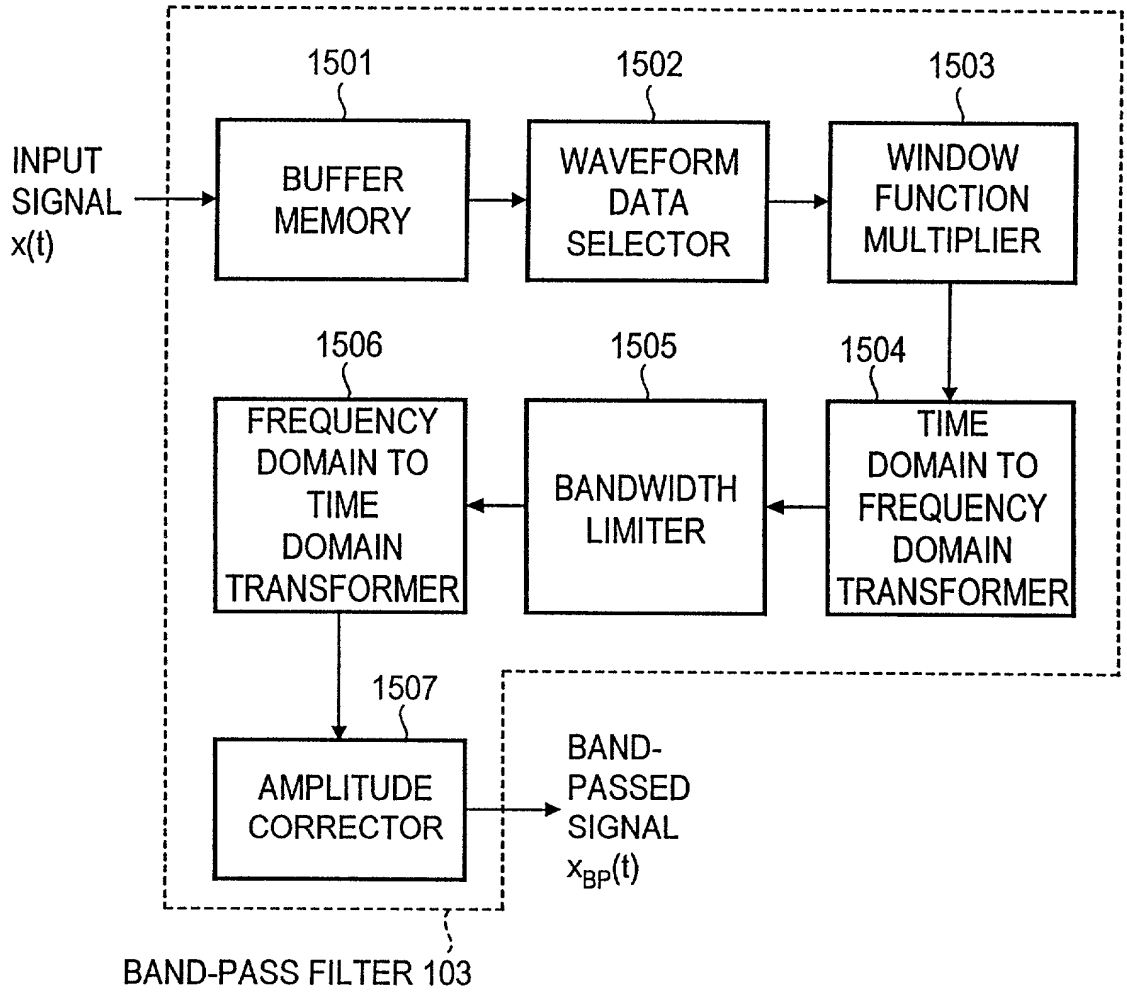

1501
1502
1503
INPUT SIGNAL x(t)
BUFFER MEMORY
WAVEFORM DATA SELECTOR
WINDOW FUNCTION MULTIPLIER
1506
1505
1504
FREQUENCY DOMAIN TO TIME DOMAIN TRANSFORMER
BANDWIDTH LIMITER
TIME DOMAIN TO FREQUENCY DOMAIN TRANSFORMER
1507
AMPLITUDE CORRECTOR
BAND-PASSED SIGNAL $x_{BP}(t)$
BAND-PASS FILTER 103

FIG. 38

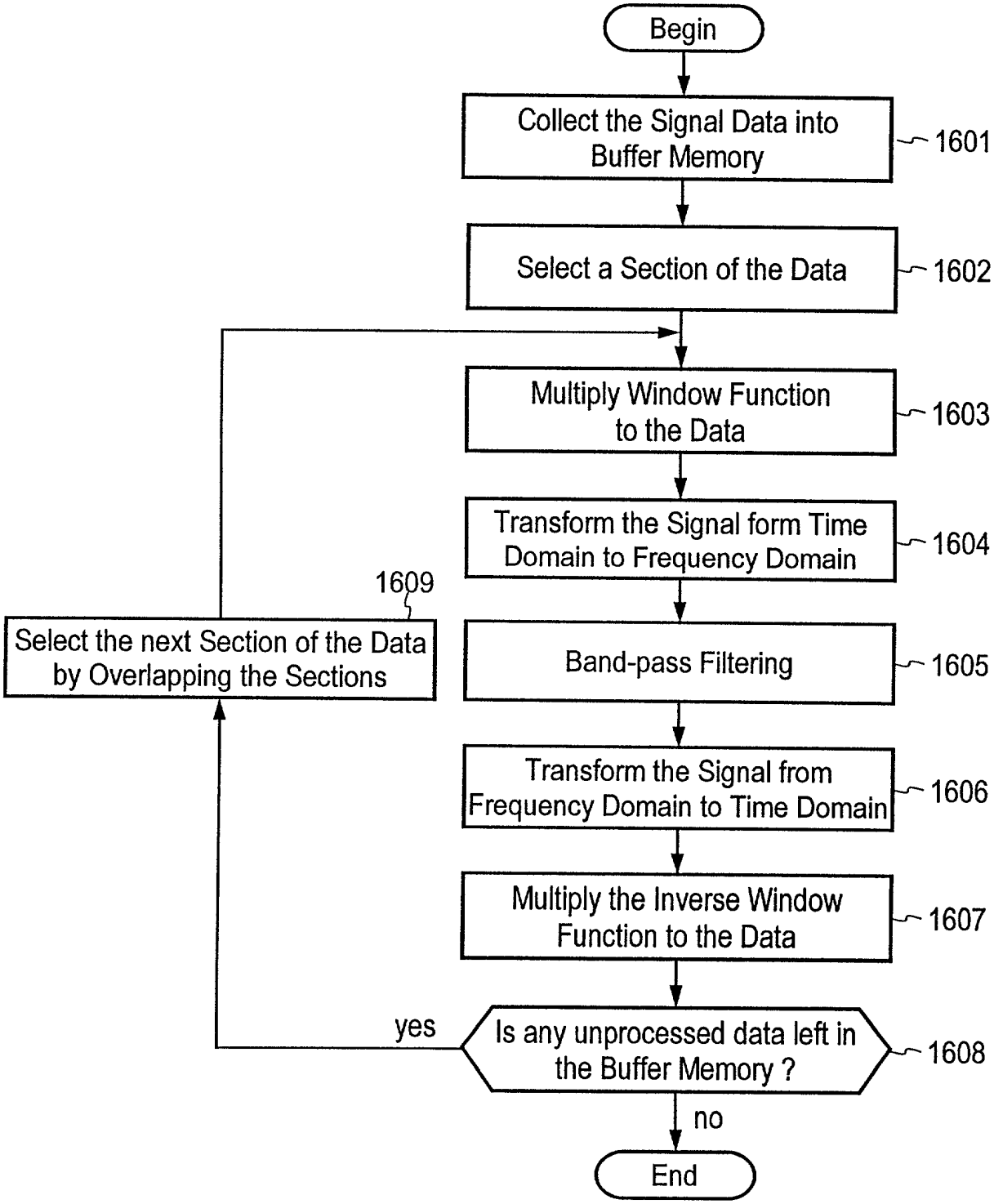

Begin
Collect the Signal Data into Buffer Memory
1601
Select a Section of the Data
1602
Multiply Window Function to the Data
1603
Transform the Signal form Time Domain to Frequency Domain
1604
Band-pass Filtering
1605
Transform the Signal from Frequency Domain to Time Domain
1606
Multiply the Inverse Window Function to the Data
1607
Is any unprocessed data left in the Buffer Memory ?
1608
yes
no
End
1609
Select the next Section of the Data by Overlapping the Sections

FIG.39A

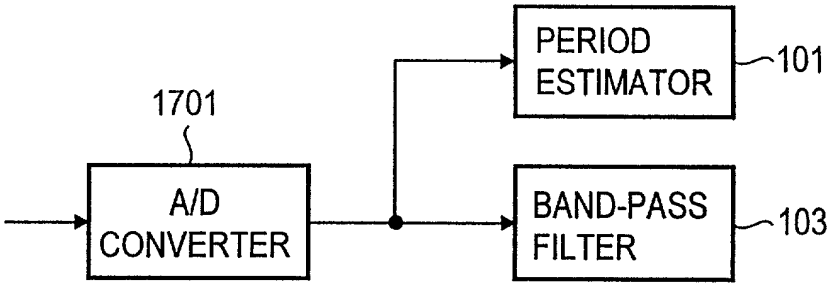


FIG.39B

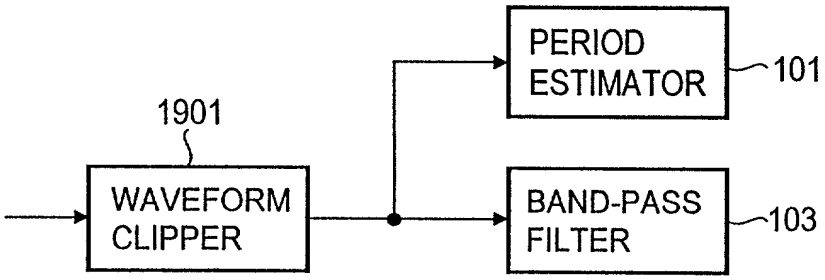


FIG.39C

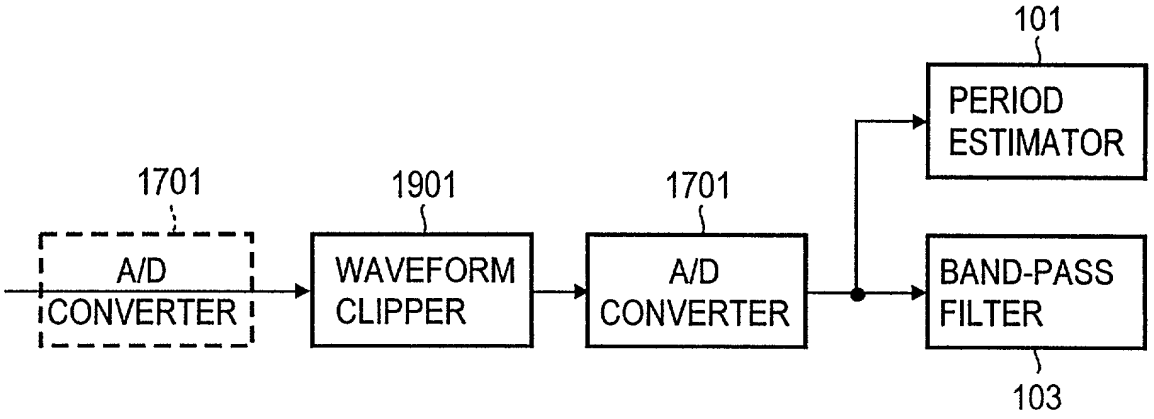


FIG. 40 A

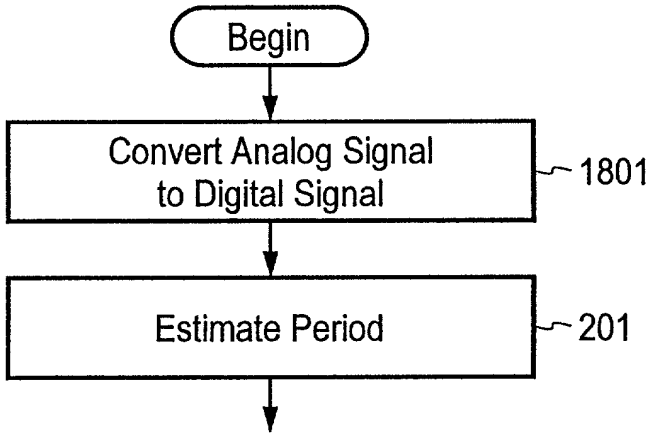


FIG. 40 B

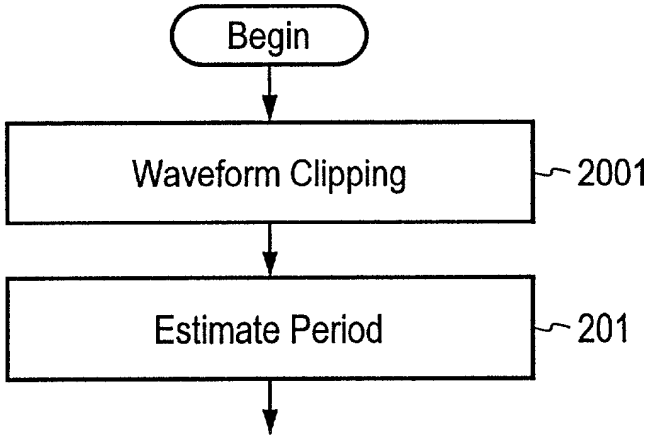
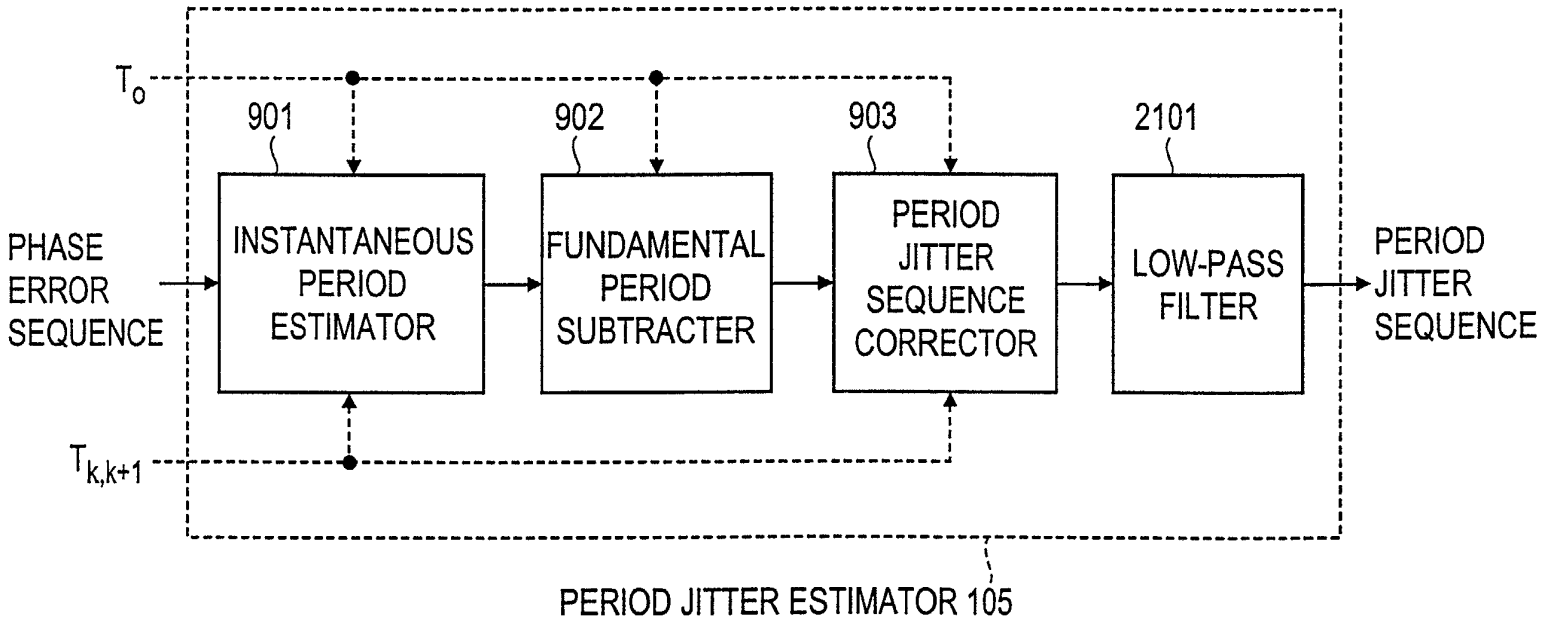


FIG.41


T_o
901
902
903
2101
PHASE ERROR SEQUENCE
INSTANTANEOUS PERIOD ESTIMATOR
FUNDAMENTAL PERIOD SUBTRACTER
PERIOD JITTER SEQUENCE CORRECTOR
LOW-PASS FILTER
PERIOD JITTER SEQUENCE
$T_{k,k+1}$
PERIOD JITTER ESTIMATOR 105